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COMPLETE SPECIFICATION

Stretchable Fabric and Method of Making same from Multiplicity of Yarn Ends

We, GROVE SILK COMPANY, a Corporation of the State of Pennsylvania, United States of America, of 150, East Grove Street, Scranton 10, Pennsylvania, United States of America (Assignee of REINHOLD FREDERICK STUEWER), do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a textile article having stretching properties superior to those exhibited by articles prepared from untreated yarn ends, and to the method of producing such article. More specifically it relates to an improvement in or modification of the invention disclosed in United Kingdom Patent Specification No. 781,030.

When synthetic fibers of the polyamide and polyester types, and in general the polymer synthetics which are formed by extruding a liquid through a nozzle, hardening and then stretching the filament, are subjected for the first time to setting operations at correlated temperature and time conditions (an operation hereinafter referred to as "pre-setting"), they thereby attain the capacity of returning toward the shape existent during the pre-setting operation, in event of later mechanical twisting or untwisting, for example. Such fibers, so treated, are referred to herein as being of stretched microcrystalline polymer material. When it is desired to increase the stretchability of a fabric made from multifil yarn, it has been proposed to set yarn in twisted form, so that the fabric is thus composed of individual knitted courses, wefts or warps, which have curls or twists in the filaments. In knitted fabrics there is a permissive stretchability in the loops formed in the knitting, and if a monofil or multifil yarn is employed which has a curled or helical form, a further stretching is permitted by the movement of the yarn from helical to straight form under the force applied.

[*Price 3s. 6d.*]

However, such helical yarns are more costly to make than straight filament yarns, and there are difficulties in preparing fabrics from yarns which have been twisted to confer a helical form, due to so-called "liveliness." Snarls may occur during the knitting and defective articles result. Machine attachments and devices are known, in which such lively yarns may be handled by maintaining them in a relatively uniform stretched condition; but even in such cases the machine adjustments are very critical, operation is difficult, and the output per machine is reduced.

It has been found that stretchable fabrics can be made from yarns which are in a non-lively or "dead" condition during knitting or weaving, and thereafter are further treated to confer upon them the desired characteristic of liveliness.

When a length of a "dead" or non-lively monofil yarn which has been pre-set is twisted about its axis, the effect is not visible in a cylindrical filament while it remains under endwise tension; but it can be assumed that the previous longitudinal molecular linkages at the surface, for example, have been distorted into helical forms. When the endwise tension is released with the ends held against untwisting, the length tends to "fetch up" into a helix or one or more lateral loops with twinned bifilar stems. When one end is released, it tends to rotate about the longitudinal axis, to release the twist. If the yarn is subjected to a setting operation while held in such twisted condition, its capability of unwinding is reduced. For example, if a right-hand twist of 50 turns per inch is given such yarn, and setting accomplished in water at, say, 180 degrees F., the yarn will untwist by, say, 13 turns per inch (residual 37 turns twist) and is then "dead" (i.e. without liveliness) although the original condition has not been gained. In general, the required amount of untwisting depends inversely upon the setting temperature, other conditions being the same:

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for example the " dead " condition may occur at 14 turns untwisting (36 turns residual) after treatment at 170 degrees F., or at 12 turns untwisting (38 turns residual) at 200 degrees F.

The behavior of a synthetic yarn is largely determined by its history. Its disposition upon heating above room temperature, when without external stress, is to assume the shape or relative position of the parts existent during the last prior setting operation: and it may develop internal stresses when detained against free return to such shape or relative position. In general, the effect of a setting operation can only be totally dissipated by a treatment which is more rigorous than the setting itself. For example, a yarn which has been twisted and set at 200 degrees F. in hot water undergoes a change of shape or relative positioning which is not completely eliminated by a later immersion in water at such temperature; and in practice some of the imposed twist will not be dissipated by treatment at 212 degrees F.

It has been found that a yarn, pre-set at a relatively high temperature, which is then given a right-hand twist of 50 turns per inch and then set at a lower temperature while held in such twisted state, can then be brought to a non-lively or " dead " condition by partial untwisting by, say, 13 turns; and, furthermore, when the yarn in this non-lively condition is again subjected to a heat-treatment, it is activated and tends to untwist further by, say, 12 additional turns, thereupon exhibiting a liveliness condition corresponding to a tendency to untwist left-handedly by 12 turns. Similarly, if the original twisting is left-hand, and the same succession of operations is performed, the final product exhibits a liveliness condition corresponding to a tendency to untwist right-handedly by 12 turns. The amount of re-assumed liveliness can be determined by the conditions of the successive heat treatments. A pre-set yarn which, having been rendered " dead " by the said twisting, twist setting at a lower temperature and partially untwisting, can, by further heat treatment, be given a tendency to untwist further, is hereinafter said to have a " potential twist " or a " twist potential."

It has thus been found feasible to produce stretchability in a fabric by twisting and setting a pre-set yarn, effecting untwisting until the yarn is non-lively or " dead," in which condition it can be used in making a fabric, and then subjecting the fabric to a further treatment for developing liveliness in the yarn by a release of a further part of the previously set state.

This behavior is likewise exhibited when a yarn A is given an original right-hand twist with a further treatment as just described, and an original yarn B is given the like treatment with the left-hand original twist: and that when a third monofil yarn C which has not been pre-set and then twisted is also introduced during the forming of the fabric, the fabrication can be accomplished with the three yarns A, B and C in " dead " condition so that knitting or weaving is easy. Thereafter, the further treatment produces release in the yarns A and B so that they develop liveliness: and the same treatment also accomplishes a setting in yarn C, so that it likewise responds to stretching by its elastic tendency to return to the prior condition.

Due to the importance of history of the yarn, it is necessary to subject the yarn as received to a pre-setting treatment, prior to twisting, which is more rigorous than any later treatment to be given. This fixes in the material a condition of straightness, in line with what is sometimes called " memory." Thereafter, when a twisted and re-set yarn is again treated in a relaxed condition, it tends to return toward the original relative positioning of parts imposed by the pre-setting.

EXAMPLE I

A 15 denier nylon monofil, as received, was subjected without twisting to a pre-setting at 265 degrees F. under steam pressure (25 lbs. pressure) for 20 minutes. A part A of the yarn was twisted to the right on a machine adjusted for 51 turns per inch and then set at 200 degrees F. in moisture-saturated air while held at such twist. The yarn had liveliness; but this was removed by mechanically untwisting (to the left) 12 turns per inch, and the yarn was wound on a bobbin or shaft, and then rewound on a knitting package. A specimen taken immediately after untwisting indicated a tendency for reverse (rightward) twisting, that is, an excess untwisting had been accomplished. About 4 hours after the untwisting, the specimen had the same appearance and " deadness " as in the pre-set state. Another part B of the yarn was twisted to the left with the machine adjusted for 50 turns per inch, set at 200 degrees F. in moisture-saturated air while held at such twist; mechanically untwisted (to the right) 12 turns per inch, and then likewise wound and rewound to a knitting package. A specimen thereof also indicated immediatey an exccss of untwisting, which had disappeared in about 4 hours' time so that yarn B likewise had the same appearance and " deadness " as in the pre-set state. At this time, yarns A and B were employed in knitting successive courses, followed by knitting with a non-pre-set yarn C of the same 15 denier nylon monofil, which had not been treated by twisting or setting. Other specimens of yarns A, B similarly treated, and of yarn C, can be employed in multi-feed knitting systems, with the first feeding device delivering yarn A, the second feeding device delivering yarn B, and the third feeding device yarn C; this succession being repeated. The fabric had the appearance of being knitted from yarns of " dead " character.

The fabric was then subjected to a treatment in boiling water for 1 to 10 minutes, whereby a release of set was accomplished in yarns A and B, and a setting operation was accomplished on yarn C. The major effect occurred within 1 minute. Therewith yarns A and B developed a liveliness, with shrinkage of the knitted size: and yarn C received a setting in its looped condition, so that it exhibited less stress and tendency to straighten than in the fabric as knitted. The fabric could be stretched from its shrunken size after treatment, to essentially the same length as prior to the set-releasing treatment.

As will be evident from the above description, the yarns A and B tend to become lively again corresponding to a small number of turns of twist in a few hours, and hence it is desirable to untwist the yarn immediately after setting by a few turns more than necessary to render the yarn dead at that time so as to compensate for this and to ensure that the yarns A and B will be " dead " at the time of knitting. This tendency for the yarn to become lively again is essentially complete after 24 hours; so that stored yarns do not exhibit thereafter a continued tendency to become lively from the " dead " condition.

The set-releasing treatment can be varied. When stockings are knitted and seamed before the releasing treatment, the release can be effected by immersion in boiling water, by immersion in a dye bath at 160 degrees F., or by loose boarding and placing in a chamber with steam at 240 degrees F. for a minute. Also unseamed stockings have been heated in steam at 240 degrees for a minute, and then seamed. In each case, a satisfactory liveliness developed in the fabric.

The operations can also be conducted with a multi-feed knitting system, in which a first feeding device serves to deliver several courses of yarn A, followed in turn by the second feeding device delivering several courses of yarn B, and in turn by the third feeding device delivering several courses of yarn C. These successive groups of courses thus can provide visually apparent bands in the fabric.

Likewise, after pre-setting, twisting and twist-setting of the yarn A at a lower temperature, two or more ends of such yarn, which are right-twisted, may be paired or placed adjacent and parallel to one another and then twisted together with a left twist to the dead condition. Such paired yarn requires fewer turns of left twist to achieve the dead condition than each of the yarns would require individually, as a result of the yarn ends being twisted upon one another during the untwisting. A similar action may be taken with yarn B (i.e. using two left-twisted ends) noting that the several twistings and untwistings are respectively opposite to those employed with the ends for yarn A.

Example II

A 15 denier nylon monofil was subjected without twisting to pre-setting at 212 degrees F. in saturated steam; right-twisted 51 turns per inch, set at 180 degrees F., and mechanically untwisted (to the left) by 10 turns per inch, whereby a non-lively yarn A was obtained for knitting. Yarn B was prepared in the same fashion, but with the corresponding twistings of opposite hand. Yarn C was prepared by taking the original monofil, without pre-setting or twisting. The yarns can be knitted with a three-carrier system, and the fabric treated in hot water at 180 degrees, thereby shrinking and becoming lively.

In general, for a given condition of pre-setting by prior history, the closer the setting temperature approaches the pre-setting temperature, the less the liveliness of the set material. Thus, with the above pre-settings at 265 and 212 degrees F., setting of the twisted yarns at successively higher temperatures will give yarns with different and sucessively lesser amounts of liveliness which are thereafter eliminated, under this invention, by correlated untwisting. When the pre-setting was at 265 degrees F., under the first example, setting at 200 degrees left 12 turns per inch of relative liveliness, with 39 turns residual in the "dead" material and potentially in major part available for re-establishing liveliness when the relaxed yarn A or B was heated after the knitting. If the twist-setting is at a lower temperature, the liveliness is greater, and a larger number of turns per inch must be untwisted to attain a non-lively condition. If the twist-setting is at a higher temperature, less turns need be untwisted to attain non-liveliness.

A like relation exists between the conditions of twist-setting and set-releasing for yarns A and B. A yarn as in Example I, which has been twisted and twist-set at 200 degrees F., and then untwisted to " dead " condition, shows different amounts of development of liveliness in the fabric at different temperatures. For examples, at 160 degrees F., specimens underwent release of 10 turns with 29 turns still residual: at 180 degrees F., release of 16 turns with 23 turns residual; at 212 degrees F., release of 22 turns with 17 turns residual; at 240 degrees in steam, a release of 26 turns with 13 turns residual. The released turns represent the liveliness which can be conferred upon the fabric and yarns from the " dead " condition at knitting.

Comparably, when the twist-setting was at 170 degrees F., with untwisting 14 turns to " dead " condition, the yarn specimens underwent a release of 13 turns (24 turns residual) at 140 degrees F.; a release of 18 turns (19 turns residual) at 180 degrees F.; and a release of 26 turns (11 turns residual) at 212 degrees F.

As a further comparison, yarn was pre-set

as in Example II (212 degrees F.), twisted 50 turns, and specimens were twist-set at temperatures of 180, 160 and 140 degrees F. Ten turns per inch were untwisted from the specimen twist-set at 180 degrees, and 12 turns from the others, to get an essentially "dead" condition. All specimens were then subjected to set-release in boiling water (212 degrees F.) for 10 minutes, after a brief subjection to wet atmospheric steam for convenience to avoid snarling. The specimen twist-set at 180 degrees had a release of 22 turns per inch (18 turns residual); that at 160 degrees, a release of 25 turns (13 turns residual); and that at 140 degrees, a release of 27 turns (11 turns residual).

The required increment of stretchability, economic conditions, and the schedule for dyeing, boarding and like after-treatments of the fabric, determine the selection of the temperatures to be used.

When fabrics, from yarns pre-set at 212 degrees F. in moisture-saturated air, were exposed to steam at 15 lbs. pressure (250 degrees F.), the fabrics stretched less distances and had lost some resistance to stretching, as compared with those in which the release was effected at lower temperatures. The presetting can be at a temperature of 212 degrees F. and the twist-setting at temperatures as low as 140 degrees F., and yet stockings knitted from the partially untwisted yarns can be subjected to boarding under 15 lbs. steam pressure (250 degrees F.) after the releasing treatment, and exhibit significant stretch properties. Such stockings exhibit a somewhat less resistance to stretching than those made of yarn pre-set at 265 degrees F. (25 lbs. steam pressure) and given the same twist-setting treatment, with a boarding at 15 lbs. steam pressure.

It has been found that the amount of liveliness or tendency to untwist exhibited by a monofil which has been twisted and twist-set has a very slight increase with the turns of twist introduced: but is more critically dependent upon the twist-setting temperature. Thus 15 denier nylon yarns can be subjected to twisting through 30 to 100 turns per inch and conditions or twist-set at 160, 180, 200 and 212 degrees F. in moisture-saturated air or steam; and the yarns untwisted to a "dead" state. Yarns twisted by 30 turns and twist-set at 180 degrees F. required 10—12 turns untwisting, with a residual 18—20 turns remaining in the "dead" yarn: yarn twisted 65 turns, and twist-set at 180 degrees F. required 12—14 turns untwisting, with a residual 51—53 turns left in the "dead" yarn. In each case, heating of the fabrics in boiling water resulted in the release of the major part of the residual twist, as indicated by the values above: but it will be noted that yarn originally twisted 30 turns can develop 20 turns of liveliness at most, while that twisted 65 turns can develop up to about 40 turns of liveliness without employing strenuous releasing conditions.

In practice for knitted stockings of nylon of around 10 to 15 denier, a range of 30 to 60 turns per inch of original twist, with twist-setting at 160—180 degrees F., and the removal of 8—16 turns for a "dead" condition, represent presently preferred commercial practices in preparing yarns A and B, which respectively were twisted right and left after the pre-setting. For other fabrics, e.g. woven crepes, higher final liveliness is desirable, and can be attained by higher original twists, up to 100 turns per inch for 15 denier yarn for example, a more extensive twist-setting so that less turns need be removed to produce a "dead" condition, and by more severe set-releasing temperatures employed upon the fabric while it is in a relaxed condition.

It has been found desirable to effect presetting without significant tension in the yarns, so that shrinkage may occur. This can be accomplished by winding the yarns upon tubes having collapsible corrugated coverings and treating the yarns thereon, or by difference of the yarn speeds at entering and leaving the pre-setting region.

The time required for the release of residual turns of twist is very short. A large effect occurs as the material enters the temperature zone (e.g. hot water), and only a small increase occurs after the first minute. In tests with single strands, it was found that there was no significant difference between 10 and 30 minutes treatment.

A characteristic of this invention is the employment of yarns A and B which are essentially "dead" and hence easy to knit or weave, but which develop liveliness upon a set-releasing heat treatment of the fabric, resulting in tendencies of the individual yarns to twist and skew, but with this tendency compensated by the presence of right-hand and left-hand twisted yarns adjacent one another in the courses or bands; and, in addition, in the employment of a yarn C which does not have a potential or stored effect by which it exhibits a liveliness due to release of such potential upon the treatment of the fabric for releasing the "set" in yarns A and B. Yarn C, however, undergoes a setting during such treatment, as distinguished from the set-release in yarns A and B, and thereby it accepts a position in the fabric which is exhibited by elasticity of the yarn C when the fabric is stretched.

In tests made upon unknitted monofil yarns, to determine the releasing action, a vertical tube was provided and connected to a source of steam or moisture-saturated air for upward flow. Small skeins of 10 threads, and single loops, were formed 44 inches in circumference; a weight of 0.25 grams was placed in the bight; and the skein or loop slowly lowered

into the tube, with counting of the number of twists made by the skein or loop.

In one series of tests, 15 denier nylon yarn was pre-set for 20 minutes by steam at 25 lbs. pressure, with allowed shrinkage; followed by inserting the number of turns indicated below as "TWIST," and conditioning, at the temperature (F.) stated as "TWIST-SETTING." Lengths of the yarn were then mechanically untwisted by the number of turns stated as "TWIST REMOVED." The skeins were made, lowered into the tube and held for ten minutes: the liveliness thus developed, being the turns developed by the twisting skeins, are in the column "SKEIN," and by single loops similarly handled, in the column "LOOP." The specimen yarns were also employed in knitting, in the twist-set and partially untwisted state: and the results are given in the "KNIT" column by the reference S indicating satisfactory knitting with ordinary machines and adjustments, U indicating knitability upon special equipment to avoid snarls, and C denoting that care was needed in knitting upon standard machines. Yarn remaining on the knitting packages was tested, after two weeks from the twist removal, to determine the liveliness at that time; and the values are reported in the column "AFTER 2 WEEKS."

TABLE I

Twist	Twist-Setting	Twist Removed	Total Turns		Knit	After 2 Weeks
			Skein	Loop		
51	200	12	213	382	S	0
51	170	12	282	554	C	2.2
30	180	12	210	300	S	0.3
30	180	10	268	338	C	1.5
30	160	12	235	348	S	1.2
30	160	10	245	360	U	1.9
40	180	14	226	380	S	0
40	180	11	242	415	S	1.7
40	160	12	248	463	U	2.0
65	212	12	206	397	S	0
65	180	12	290	547	S	1.6
100	212	12	254	490	S	0.3
100	212	10	277	522	C	2.2
100	180	14	336	665	U	1.3

The knitting tests indicated that the liveliness values found by the test for 10 strands were not strictly comparable, if yarns of considerably different twists are involved. Thus a 51 turn specimen showed a liveliness of 213, but gave a better fabric than a 30 turn specimen with a liveliness of 235, when the fabrics were given like releasing treatments.

The liveliness values found with single loops appeared to be better indications, as to the fabric which can be made, than the values for the skeins.

The liveliness in some of the yarns, so that special knitting conditions were desirable, was due to the selection of an untwisting action of the throwing machine which did not bring the partially untwisted yarn to a "dead" condition at the time of knitting. Obviously, such effects can be avoided by a different selection of the number of turns for untwisting following a given treatment. This is corroborated by the last column in Table I, showing the liveliness present two weeks after the mechanical untwisting, from which it will be noted that yarns having liveliness of 2 turns or over per inch required special care of special equipment

to avoid snarls, and that even lesser liveliness may cause difficulty. The liveliness of the yarn, at completion of the twist-setting, can be closely estimated by observing its behavior in a twist-tester, using lengths of 10 or 20 inches and observing its tendency to form loops after a given number of turns have been removed and then re-twisting or further untwisting until the yarn appears "dead"; and then untwisting the rest of the yarn by a corresponding number of turns per inch plus, for example, about 2 turns per inch for 15 denier, 51 turns yarns to provide for the automatic adjustment in the yarn during the time between mechanical untwisting and knitting.

The fabric as knitted is composed of yarns which have potential ability to become lively upon the later treatment, along with yarns which have no such potential as employed in the knitting machine. In the foregoing, these yarns have been described as of the same sizes, with yarns A and B having individually undergone respective treatments by pre-setting, right or left twisting, setting and untwisting. The yarns A and B can be employed with the non-potential yarn C by a multiple-feed system for providing successive courses in a circular knitting machine, for example: or providing successive pairs of courses in a flat bed knitting machine.

It is also feasible to employ the yarns in other fashions, by which the advantages of their differential behaviors can be employed in producing a fabric which has excellent elastic stretching properties.

As an example of practice, a stocking may be knitted by three carriers with yarns A, B and C, and the welt or heavy section is formed by these carriers with, for example 15 denier yarn, and a fourth carrier having a 20 denier thread D which has not been treated, i.e. the yarn D in the fourth carrier is "non-potential" in having been so prepared that it is ready to respond to the treatment of the fabric which is accomplishing the release of a potential effect in yarns A and B, but therewith assuming a relatively stressed condition due to the development of liveliness in yarns A and B, together with a setting of the yarn C in the shape thus produced. A first course can then be formed with the 20 denier end D and a left-twisting 15 denier end of yarn A laid together in the course; with a next course containing the 20 denier end D and an untwisted 15 denier end of yarn C; and a third course containing the 20 denier end D and a right-twisting 15 denier end of yarn B. The courses are then repeated in order. The foot of the stocking can be made in the same fashion. When this fabric is subjected to a treatment with heat and moisture, yarns A and B undergo a set-releasing, and yarn C, along with the 20 denier yarn D laid by the fourth carrier, receives a setting effect. The yarn C, and the yarn D for the fourth carrier, need not be nylon. For example, the yarns A and B can be nylon or a like material having the characteristic of becoming set with permissive set release later, whereby to establish the stretch property, while the other yarns C and D may be of untreated nylon, silk, or other fiber, for conferring other desired properties upon the fabric made. As an example, the fourth carrier described above may have its 20 denier yarn provided by multifil nylon, whereas yarns A, B and C are of monofil nylon. Cotton or wool can thus be introduced in knitting men's socks, with the yarns A and B serving for establishing the stretch properties.

Example III

Practice with multifilament yarns can be conducted for example by subjecting a 30 denier 10 filament nylon yarn to pre-heating for 20 minutes at 265 degrees F. in moist air, while wrapped on tubes covered with corrugated paper to permit shrinkage. One end of such yarn was then twisted 51 turns to the right, twist-set at 200 degrees F. in moisture-saturated air for one hour, and then mechanically untwisted 21 turns, to give a dead yarn A which was then sized. A similar yarn end B was prepared but with the first twist to the left, and with the untwisting to the right, to give a dead yarn, and followed by sizing. A third end of the original yarn, without pre-setting, was twisted 30 turns left and then twist-set at 180 degrees F. to form a yarn C of non-potential type. Each of the original ends had a minor original twist, but the effect of this was not apparent in the final result. The three yarns were knitted into a hosiery fabric, with successive courses being knitted from yarns A, B and C on a conventional three-carrier knitting machine. The stockings had the appearance of conventional three-carrier fabric when removed from the machine. Upon immersion of the stockings in boiling water for one minute, the potential twist of yarns A and B was released with shrinkage of the stockings; yarn C responded to the shrinkage and twisting of yarns A and B and underwent a setting effect, and a highly stretchable fabric was produced. The stockings were then dyed and finally boarded at 240 degrees F. in a steam chamber.

In work with multifilament yarns, where the appearance of broad bands of different light reflection, or streaked appearance, is undesirable, it is preferred that the final twist in yarns A, B and C be essentially the same, and one or a few courses be formed with each successive yarn end A, B or C, during the fabrication: so that the final product does not exhibit bands having differing light reflection due to the differences in the final twists. In this Example III, it will be noted that yarn C has been given a conventional treatment, without the pre-setting as employed for yarns A and B. Where a striped appearance in a

fabric is desirable, in band form, the final twist may be of different amounts, and attained by having the yarns at the time of knitting with differing potential twists or conventional twists therein.

In the accompanying drawing, Fig. 1 is a greatly enlarged illustration of a part of a fabric made from three yarns laid in successive courses in accordance with this invention.

Fig. 2 is a diagrammatic showing of the steps of treatment of the three yarns.

In Fig. 1, the portion of fabric is assumed to have been knitted with a first course of a yarn C of untreated monofil nylon, with forming of the usual loops therein, illustrated in the drawing by absence of shading along the filament, these loops being somewhat more open than shown in Fig. 1, in the as-knitted condition, as is known to those skilled in the knitting art. The next lower course is provided by a left-twisting yarn A of nylon monofil which is distinguished in the drawing by the vertical designating lines thereon. The third course is provided by a right-twisting yarn B of nylon monofil, its loops being designated by horizontal lines. For the rest of the fabric, the courses of yarns C, A, B are repeated. After knitting, the fabric was subjected to the treatment whereby the potential effects in yarns A and B underwent a release, and therewith the loops of yarns A and B have respectively twisted toward the left and right, with each yarn having a final position resembling a helix, with the loops tending to turn over, so to speak, from the more planar position occupied by the loops of yarn C, therewith causing a contraction or shrinkage in the fabric, which contraction later can be utilized in stretching back to the size normally permitted by a similarly knitted fabric in which all of the courses are of a yarn such as yarn C. During this treatment, the yarn C has undergone a setting in the condition occupied in the knitted fabric, with a modification due to the shrinkage as the liveliness develops in yarns A and B. Therefore, upon lengthwise pulls between the right-hand and left-hand ends of yarns C in Fig. 1, the fabric will stretch, but the elastic resistance produced by this setting of yarns C leads to a property by which yarn C assists in the production of a high stretching effect in the fabric.

In Figure 1, the courses of yarns A, B and C provide single-course bands from yarns of different characteristics at the time of knitting; but it will be understood that fabric may be prepared in which such a band may comprise two or more successive courses of yarn of one given characteristic, followed by a band of one or more courses of yarn of a different characteristic, and then by a third band of one or more courses of a yarn of a third characteristic.

It is particularly to be noted that one-third of the yarn employed in Fig. 1 is of non-potential monofil nylon, for yarn ends C; while the yarns ends A and B have been treated by pre-setting, twisting, and partial untwisting and are thus of potential type. Therefore, one third of the material is less expensive than the rest, so that there is a reduction in cost for the final fabric over its manufacture totally of either lively yarns or of yarns having potential liveliness. Yet all of the yarns employed can be knit in the "dead" condition, with release of potential liveliness in yarns A and B, and the setting of yarn C in a form where it exhibits elastic stretchability.

In Fig. 2, the treatments for the three yarns of Fig. 1 are set out by a diagram. Yarn A is subjected to a pre-setting operation *20*, followed by right-hand twisting in an operation *21* and a twist-setting operation *22*. Yarn A is then partially untwisted in an operation *23* with an excess of untwisting so that any residual automatic untwisting is compensated for and after a period of a few hours the yarn is at a "dead" condition. Yarn B is similarly subjected to successive operations of pre-setting *30*, left-twisting *31*, twist-setting *32*, and a partial untwisting *33*. Yarn C is used in the non-potential condition as received from the manufacturer. The yarns A, B and C are then introduced into individual carriers in a knitting machine and knitting performed as indicated at *40*. The fabric is then subjected to the set-releasing and setting treatment *41* as described above, and then has a form as indicated by Fig. 1.

It is preferred to perform the heating operations in steam or moisture-saturated air. However, other vapors and gases may be employed; noting that oven heating requires higher temperatures for producing a given effect, and that the material must not be heated at any point to the adhesive or melting temperatures of the synthetic base.

Other stretched synthetic fibers, such as polyesters, give comparable results.

A polyester (Dacron: register Trade Mark) multifil yarn of 40 denier (34 filaments) can be pre-set for 20 minutes in steam at 25 lbs. pressure while free to shrink. Ends A and B of such yarn can be respectively twisted right-hand and left-hand with 20 to 100 turns per inch, and then twist-set at a lower temperature. The yarns A and B are then mechanically untwisted, to give a substantially "dead" yarn at the time of knitting. The yarns A and B are then knitted with non-potential yarn C, to form fabric: the goods upon immersion in boiling water become highly stretchable, by release of the residual or potential twist effect in yarns A and B, and the setting in yarn C.

In one specimen of Dacron, twisted 50 turns, and twist-set at 212 degrees F., 9 turns were removed, and a liveliness of 32 turns was produced upon the release. In another specimen, twisted 50 turns and twist-set at 180 degrees, with removal of 12 turns, a liveliness

of 30 turns was developed. In a third specimen, twisted 100 turns, and twist-set at 180 degrees F., 14 turns were removed, and a liveliness of 73 turns developed upon release.

The effect upon yarns of different sizes are comparable, account being taken of the size. Upon pre-setting monofils of 10, 20 and 40 denier for 20 minutes in steam at 25 lbs. pressure, twisting 51 turns per inch and twist-setting at 180 degrees F. in moisture-saturated air (sometimes referred to as 180—180, as the wet and dry bulb thermometer readings are the same), the apparent liveliness was different. The 10 denier yarn became " dead " when untwisted 13 turns, the 20 denier yarn at 10 turns, and the 40 denier yarn at 8 turns.

The effects are likewise obtained with multifil yarns, as indicated by the above example with polyester yarn. Such multifil yarns are presently delivered commercially with about a half-turn per inch, usually left-hand: and when 20 or more turns per inch are given to it, the effect of such original twist is insignificant whether the further twist is right or left hand. When an original multifil yarn of 20 denier (7 filaments of about 3 denier each) is pre-set for 20 minutes in steam at 25 lbs. pressure, and then twisted 51 turns and twist-set at 200 degrees in humid air, the liveliness required removal of about 14 turns per inch: that is, more turns were removed than with a monofil of 20 denier. Another part of the same original yarn was pre-set, twisted in the opposite direction, twist-set, and about 14 turns per inch removed. These yarns A and B are " potential " in having therein a twist-set effect which can be released by a subsequent treatment, and are present in a " dead " condition for knitting along with a non-potential yarn C, which for this example may be a conventionally treated yarn of the same original stock, with 35 turns of left-twist. The yarns A, B and C were then knitted in successive courses. The yarns knitted satisfactorily, each being essentially " dead." The fabric was treated in boiling water and developed liveliness in the yarns A and B, and a satisfactory stretch in the fabric.

The amount of original twisting desirable for a given case depends upon the size of the filament, and the purpose of use. It must be sufficient to permit the untwisting, after setting, so that the yarn is non-lively at knitting, and to have a potential effect available upon set-release, to produce the desired liveliness of the yarn in the fabric. With filaments below 10 denier, e.g. at 1 or 2 denier, the twisting effect or liveliness in the fabric yarn may obviously be correspondingly higher: while at 20 and 40 denier, significant effects in wide gauge knit fabrics for example can be obtained with twists in the yarn of the fabric of less than 10 turns per inch, and even lower twists for greater diameters.

The removal of the liveliness from the twist-set yarn need not be accomplished upon the individual yarn. For example, two monofil or multifil yarns can be pre-set, twisted and twist-set, with both yarns having a left twist of, for example, 51 turns per inch. The two ends, without mechanical untwisting to remove the liveliness, can be plied together with right-twist of, say, 8 turns for 15 denier yarn: the bifilar product is then essentially " dead " and can be so knitted because the plying twist has removed the liveliness. Two such bifilar yarns A and B, respectively originally twisted right and left, can then be employed with a non-potential yarn C to produce a fabric. The fabric can then be treated for set-release whereupon the potential liveliness is developed in yarns A and B, with the respective effects of right-twist and left-twist, which with the specific example hereinbefore referred to in this paragraph amounts to about 25 turns, and with a setting of the yarn C as described above. The two multifil ends may be, for example, 70 denier, 34 filament yarns.

The temperature conditioning given to the twisted material can be referred to as " twist-setting " in action upon yarns A and B; since its effect is to relieve some of the twisting stresses so that the yarns thus treated will not untwist completely when left free to adjust themselves, but will have stored within them a condition of potential or residual untwisting ability although this is not exhibited by physical tendency to untwist further; and since it involves a second setting upon yarns A and B subsequent to the historical treatment which pre-sets the filament or subsequent to the pre-setting for stabilizing various yarns to a suitable condition prior to heat treatment. It will be noted that if the third yarn C is capable of setting, such an action is established during the treatment which is given to the fabric.

The treatment of the yarns or fabric therefrom, by which such residual or potential twisting ability of the yarns is availed of for inducing liveliness therein, can be referred to as a " releasing " or " set-releasing " operation, since it causes residual or potential stress, resulting from the original twisting of the pre-set yarns, to become effective by release of the effect of the twist-setting.

Characteristic of this invention is the preparation of yarns A and B which can be knitted in essentially " dead " or non-lively condition but have within them the potential ability to attain lively or twisting states thereafter even when present in a fabric, and the preparation of a fabric from such yarns in conjunction with yarn C, and the production in such fabric of the lively state of the yarns A and B whereby the fabric contracts and assumes a uniform condition of stretchability.

The examples are illustrative; and the invention can obviously be practised in many other ways in accordance with this disclosure and the scope of the claims.

WHAT WE CLAIM IS:—

1. The method of making a stretchable fabric, which comprises knitting successionally with two yarns of stretched microcrystalline polymer material which yarns, in themselves, are dead, but have potential twists therein, one said yarn having a right-twist potential and the other having left-twist potential, and a third dead yarn having no twist potential, whereby to produce a fabric, and then subjecting the fabric to a set-releasing treatment effective to activate potential twist and thereby establish liveliness in the first said two yarns.

2. The method of making a stretchable fabric, which comprises knitting successionally with a first yarn which, in itself, is dead, but has a potential twist therein in one direction, then with a second yarn which, in itself, is dead, but has a like potential twist in the other direction, said first and second yarns being of stretched microcrystalline polymer material, and then with a third dead yarn having no twist potential, whereby to produce a fabric; and then subjecting the fabric to a heat treatment effective to activate potential twists in the first and second yarns.

3. The method as in Claim 2, in which the heat treatment is effective to procure a setting in the third yarn.

4. A knitted fabric, made by the method of claim 1 or 2, characterized by successions of bands of a first yarn having liveliness by a twist in one direction, a second yarn having liveliness by a twist in the other direction, and a third yarn which does not exhibit twist.

5. A fabric as in Claim 4, in which the third yarn exhibits set at the bights of its loops.

6. The method of making a stretchable fabric, which comprises preparing two ends of yarn of stretched microcrystalline polymer material and, by pre-setting each at an elevated temperature, individually and oppositely twisting the two yarn ends, setting at a lower temperature, and untwisting until the yarn ends are dead, so producing potential twists in the said two dead yarn ends; forming the said two ends in dead condition together with a third dead yarn end having no twist potential into a fabric having successive bands of said three yarn ends; and subjecting the fabric to a heat treatment at a temperature less than said elevated temperature and effective to release at least a part of the setting effect in said first two ends and procure liveliness therein.

7. The method as in Claim 6, in which the liveliness procured in said first two yarn ends causes shrinkage of the fabric, and in which said heat treatment of the fabric is effective to procure a setting effect upon the said third yarn end.

8. The method as in Claim 6, in which pairs of yarn ends of like-direction twist are brought together before the respective untwisting thereof.

9. A fabric produced by the method of Claim 6.

10. A fabric produced by the method of Claim 7.

11. The method as in Claim 6, in which the said first two dead yarn ends are each paired during fabrication with a dead yarn end having no twist potential.

12. The method as in Claim 1, in which the said first two dead yarn ends are each paired during knitting with a dead yarn end having no twist potential.

13. A stocking produced by the method of Claim 1, and characterized in that consecutive single courses are of a yarn having a potential twist in one direction, followed by a yarn having a potential twist in the other direction, and followed by a yarn not having a potential twist.

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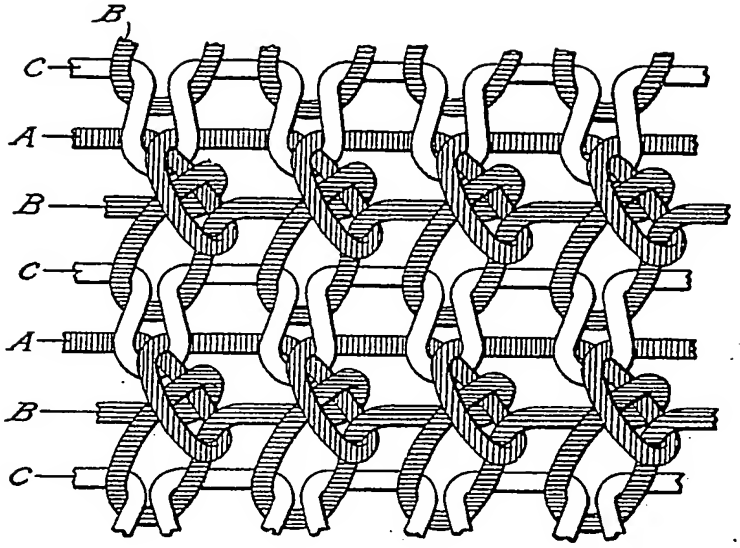
819,725 COMPLETE SPECIFICATION
1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

FIG. 1.



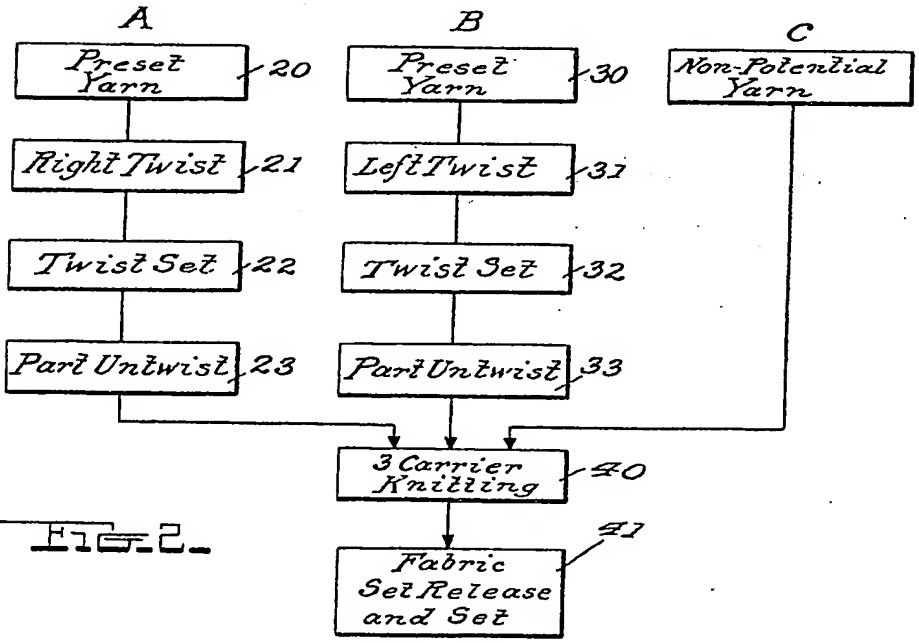


FIG. 2.